



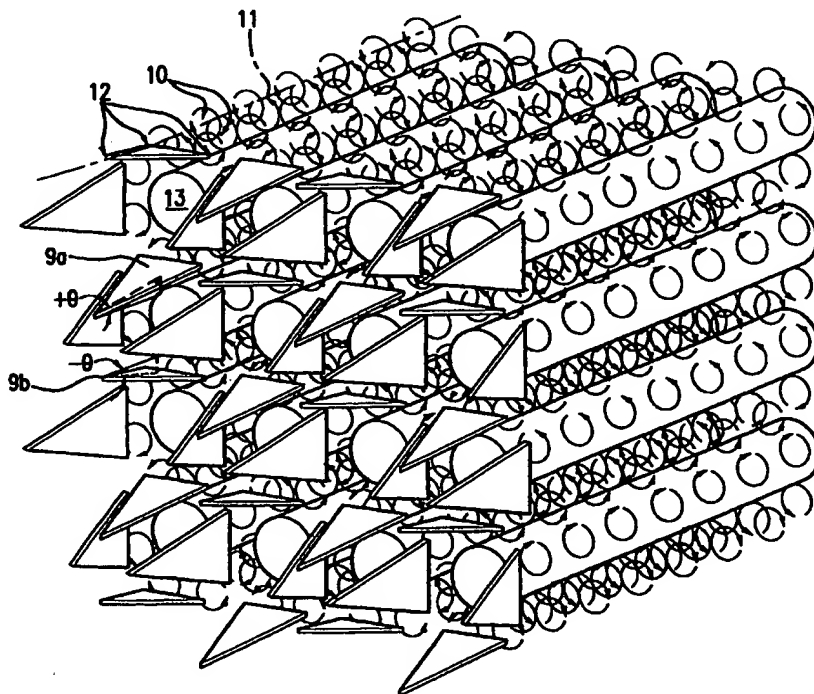
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(54) Title: METHOD AND APPARATUS FOR IMPROVED MIXING IN FLUIDS

(57) Abstract

The present invention provides an apparatus and method for accomplishing fluid disinfection by passing fluid flow through a uniform array (3B) of ultraviolet lamps having cross sections perpendicular to the direction of fluid flow that define channels (8) for the fluid flow. Positioned next to the end of each lamp (5) at the entrance of the fluid flow are triangular shaped delta wings having surfaces inclined at an angle to the direction of fluid flow. The interaction of the fluid flow with each delta wing creates a pair of vortices (10) that rotate in the same direction or in directions opposed to each other. The counter-rotating vortices (10) reinforce each other to minimize dissipation of their mixing strength as they move down the channel (8). Due to these co-reinforcing properties these counter-rotating vortices (10) more promote efficient mixing of the fluid which is required to achieve more efficient use of the light in the UV disinfection systems, along with heat and/or mass transfer in chemical reactions. Although the present invention is described in particularity as embodied in a UV reactor system, it will be understood by those skilled in the art that the present invention has equal applicability to other types of arrayed flow systems in which increased fluid mixing is desired.



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TITLE

METHOD AND APPARATUS FOR IMPROVED MIXING IN FLUIDS

FIELD OF THE INVENTION

The present invention provides a method and apparatus for improved mixing in fluids, and in particular provides a method and apparatus for improved mixing in systems that use ultraviolet (UV) radiation for disinfection of fluids.

BACKGROUND OF THE INVENTION

The use of ultraviolet (UV) radiation to kill microorganisms in air or fluid systems is well known. However, traditional UV disinfection systems are not very efficient in energy utilization. Up to twice as much power is used than is theoretically necessary because the UV light is absorbed by the fluid after penetrating only a short distance (less than 1 inch in water, for example), with the result that fluid that does not come close to the lamp is not treated. This invention proposes a method for creating large scale sustained mixing down the length of the UV lamp to bring substantially the entire volume of fluid close to the lamp for uniform treatment

Traditional arrayed low pressure/low lamp power UV disinfection systems have relatively long fluid residence times within the mixing apparatus and UV lamps of a length in the direction of fluid flow that permit sufficient mixing to be achieved to result in a low energy utilization efficiency. With the introduction of medium pressure/high power lamp systems, both the fluid residence time and the length of the lamps are decreased while the spacing perpendicular to fluid flow between adjacent arrayed lamps is increased with the result that the energy utilization efficiency is reduced even further. It has been shown that mixing baffles can improve the energy utilization efficiency. However the mixing eddies created by the baffles are short lived and require high energy input (pressure drop). Waste water disinfection systems are usually gravity fed systems that do not have large amounts of head (pressure) that can be used for mixing. The need to efficiently convert flow energy into vortices which effectively mix the fluid being treated arises because in most sewage treatment plants there is little flow energy (i.e. pressure drop) to spare. Plants are built with specific

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pressure drop requirements in mind. In a retrofit application, one may have a pressure drop of less than six inches of water to accomplish the required mixing.

To eliminate the undesirable tradeoff between energy efficiency and energy input, the present invention proposes a set of vortices essentially axially aligned in the direction of fluid flow that sustain themselves over the length that the fluid flow is exposed to the UV lamps, with the result that the production of short-lived small scale eddies which are a waste of input energy is minimized. These vortices can be produced by several means including the use of moving or stationary structures placed in the flow path such as specially shaped baffles, propellers and contoured flow tubes, among others.

The preferred embodiment of the present invention proposes the use of matched pairs of delta-shaped wings at the inlet end of an arrayed reactor to produce the counter-rotating vortices. Through use of delta wings to create co-rotating or counter-rotating vortices, the present invention permits efficient mixing with low pressure drop to allow for more efficient use of the UV light in stimulating heat and/or mass transfer in the chemical reactions causing fluid disinfection to consequently reduce the capital and operating costs of UV disinfection systems.

Accordingly, it is an object of the present invention to provide a method and apparatus to achieve increased mixing within arrayed or non-arrayed fluid flow systems so as to increase the energy utilization efficiency in such systems without degrading system energy input requirements.

It is a further object of the present invention to provide a method and apparatus to achieve increased mixing in arrayed or non-arrayed fluid flow systems by creating a set of co-rotating or counter-rotating vortices that sustain themselves throughout the entire duration of fluid travel through such systems.

It is a further object of the present invention to use delta-shaped wings at the inlet end of an arrayed or non-arrayed fluid flow system to produce co-rotating or counter-rotating vortices for the purpose of achieving increased mixing in such systems.

Accordingly, it is an object of the present invention to provide a method and apparatus to achieve increased mixing within ultraviolet (UV) fluid disinfection systems to increase the energy utilization efficiency in such systems without degrading system energy input requirements.

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It is a further object of the present invention to provide a method and apparatus to create a set of co-rotating or counter-rotating vortices in UV fluid disinfection systems that sustain themselves substantially throughout the entire duration of fluid exposure to UV radiation.

It is a further object of the present invention to use delta-shaped wings at the inlet end of a UV fluid disinfection system to produce co-rotating or counter-rotating vortices for the purpose of achieving increased mixing in such systems.

Although the present invention is described in particularity as embodied in a UV disinfection system, it will be understood by those skilled in the art that the present invention has equal applicability to other types of arrayed or non-arrayed flow systems in which increased fluid mixing is desired.

SUMMARY OF THE INVENTION

The preferred embodiment of the present invention provides an apparatus and method for accomplishing fluid mixing by passing fluid flow through an array of ultraviolet lamps lying essentially along the direction of fluid flow that define channels for the fluid flow. Positioned upstream or adjacent to each tube are triangular shaped delta wings having surfaces inclined at an angle to the direction of fluid flow. The interaction of the fluid flow with each delta wing creates a pair of vortices that counter-rotate in opposite directions to each other. These counter-rotating vortices reinforce each other to minimize dissipation of their mixing strength as they move down the channel. Due to these co-reinforcing properties, the counter-rotating vortices promote more efficient mixing of the fluid to achieve more efficient use of the light in the UV disinfection system.

Although the present invention is described in particularity as embodied in a UV disinfection system, it will be understood by those skilled in the art that the present invention has equal applicability to other types of arrayed or non-arrayed flow systems in which increased fluid mixing is desired, and that self-sustaining co-rotating or counter-rotating vortices axially aligned in the direction of fluid flow can be produced by several means other than delta wings, including the use of moving or stationary structures placed in the flow path such as specially shaped baffles, propellers and contoured flow tubes, among others.

Other details, objects, and advantages of the present invention will become apparent in the following description of the presently preferred embodiments.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 is a perspective view of the ultraviolet disinfection apparatus of the preferred embodiment of the present invention.

Figure 2a is a cross-sectional view of the delta-wing design of the present invention.

Figure 2b is a perspective view of the delta-wing design of the present invention.

Figures 3-5 are cross-sectional views of various square flow arrays which can be used with the present invention.

Figure 6 is a cross-sectional view of an alternate triangular array.

Figure 7 shows the effect of the delta wing attack angle on the delta wing drag coefficient.

Figures 8a and 8b show the relationship of delta wing aspect ratio and angle of attack on the stability of the vortices produced by the delta wings.

Figure 9 shows the relationship of the horizontal location of the vortex center line to the delta wing aspect ratio.

Figure 10 shows the relationship of the Strouhal number to the delta wing angle of attack.

Figure 11 shows the relationship of experimental pressure drop across the delta wing as a function of flow velocity.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

Figure 1 shows an arrayed fluid mixing apparatus 1, which in the preferred embodiment is utilized in an ultraviolet (UV) radiation disinfecting system. The fluid mixing apparatus consists of a frame 2 to which articulating arms 3 are attached. Each articulating arm contains a row of electrically powered lamps 5 which are each surrounded by a tube 13 made of a material that transmits ultraviolet (UV) radiation such as quartz. The arms 3 are movable between a first position 3a from which the lamps may be removed and/or replaced and a second position 3b in which the lamps 2 are arranged in array form 3b to allow a fluid 4 such as water to flow in a direction essentially parallel to the longitudinal axis of the tubes 13. When in the arrayed position 3b the lamps 5 expose the fluid 4 to UV radiation for a period sufficient to accomplish disinfection. Some of the arms 3 of the UV disinfection apparatus 1 are configured to carry spacer modules 6 instead of lamp tubes 13. By filling the void spaces in the area furthest from the tubes 13 the spacer modules 6 preserve the

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vortex flow profile and prevent fluid from bypassing exposure to UV light. The use of spacer modules 6 allows greater spacing between lamps and hence a larger cross-sectional area for the fluid flow, resulting in lower fluid velocity and associated pressure drop. The lower velocity also makes it unnecessary to provide an inlet transition region to prevent inlet pressure losses. The apparatus shown in Figure 1 is arranged in banks of four lamp tube modules 13 and three spacer modules 6. Fluid flow 4 occurs in the channels 7 between adjacent tubes 13 and/or spacer modules 6. Degradation of UV exposure is prevented by air cylinders 8 that move a cleaning mechanism to remove foreign materials deposited by the fluid 4 on the tubes 13.

As shown in Figures 2A-2B, in the preferred embodiment each tube 13 is provided with triangular shaped delta wings 9 mounted in pairs upstream of a lamp 5 at the fluid flow entrance into the tube 13 and spacer 6 array. Each delta wing 9 is designed to generate a pair of co-rotating or counter-rotating fluid vortices 10 from its trailing edge 12 as shown in Figure 3. The center line 11 of each vortex 10 is located about 25% of the wing width from each trailing tip, and has a vertical position controlled by the angle of inclination of the delta wing 9 into the flow (the "attack angle"). Essentially all of the energy dissipated by the fluid passing over the delta wing 9 goes into the large scale trailing vortices 10. As shown in Figure 3 a pair of delta wings 9a and 9b arranged together with attack angles of opposite inclination (i.e. one with attack angle $+\theta^\circ$, the other with attack angle $-\theta^\circ$) yields four counter-rotating fluid vortices 10 with the characteristics just described. By arranging many pairs of delta wings in an orderly array as shown in Figure 3, one can produce an effect similar to an array of stationary mixing propellers mounted upstream of the tube and spacer array, whereby selection of a proper propeller blade pitch and profile will result in minimization of small scale turbulence. Although an arrayed scheme such as that shown in Figures 3-6 is preferred, the essential characteristic of induced-vortex flow is that the structure used to generate the vortices be shaped and oriented so as to substantially align the axes of the vortices along the direction of the fluid flow 4. As such, a non-arrayed vortex flow system can also be produced using delta-wings 9, and both arrayed and non-arrayed systems can be produced by means other than delta wings 9, including the use of moving or stationary structures placed in the flow path such as specially shaped baffles, propellers and contoured flow tubes, among others. Additionally, co-rotating vortices 14 or co-rotating 14

and counter-rotating 10 vortices can be produced by all of these mechanisms as shown in the triangular array of Figure 6.

The mixing properties of the counter-rotating vortices 10 produced by the delta-wings 9 are further enhanced by the use of square-pitch tube 13 and spacer 6 arrays as shown in Figures 3-5. As shown in Figure 3, a square-pitch array causes the vortices 10 created by the delta wings 9 to rotate alternately co- and counter-clockwise. This counter-rotation mechanism causes the vortices 10 to reinforce each other which minimizes dissipation of their mixing strength as they move down the channel 7. Due to these co-reinforcing properties large scale vortices 10 produced by square arrays persist for a longer period of time over a greater length of the channel 8 thus requiring less energy to generate a given amount of mixing.

The delta wings 10 of the present invention were tested in a wind tunnel to confirm their fluid flow characteristics. Figure 7 shows the effect of the attack angle ϕ on the delta wing 9 drag coefficient which determines the amount of pressure drop experienced across the wing for a given fluid flow 4.¹ Figure 8a shows the relationship of aspect ratio AR and angle of attack ϕ on the stability of the vortices 10 produced by the delta wings 9.² Figure 9 shows the relationship of the horizontal location of the vortex center line 11 to the aspect ratio AR³, while the vertical location of the vortex center line 11 should remain equal to half the angle of attack ϕ for all aspect ratios AR. The relationship of vortex shedding

¹ The Lift (CL) and Drag (CD) coefficients for delta wings of any aspect ratio were calculated using:

$$\begin{aligned} (1) \quad C_L &= K_p \sin \phi (\cos \phi)^2 + K_v (\sin \phi)^2 \cos \phi & \phi &= \text{angle of attack (degrees)} \\ (2) \quad C_D &= C_L \tan \phi & K_p, K_v &= \text{obtained from Bertin and Smith (ref. 1)} \end{aligned}$$

² The aspect ratio AR was calculated using the following equation with the dimensions shown in Figure 8b:

$$(3) \quad AR = 2 \cdot b / c \quad \begin{aligned} b &= \text{span (inches)} \\ c &= \text{root chord (inches)} \end{aligned}$$

³ The horizontal position of the centerline was calculated using the following equation:

$$(4) \quad HC = 9.82 \cdot AR^{0.709} \quad \begin{aligned} HC &= \text{angle from wing centerline to vortex core (degrees),} \\ \text{and} \quad \phi_{vc} &= a/2. \end{aligned}$$

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frequency f (number of vortex revolutions obtained per unit time) to angle of attack θ and fluid flow velocity U is shown in the relationship of the Strouhal number St^4 to the angle of attack θ , as shown in Figure 10. As the fluid flow velocity U decreases so does the vortex shedding frequency f . However, this is counteracted by an increase in the residence time of the fluid in the channel 7, which can result in the same number of vortex revolutions per effective lamp length VR , which as a result causes less degradation in mixing strength with lower flow velocity U than in conventional designs.⁵

The predicted pressure drop across the delta wing 9 was calculated using the following equation:

$$(10) \quad Dp = C_D * r * U^2 * A_{wing} / (2 * A_{flow})$$

C_D = drag coefficient (equation (1))
 r = fluid density (kg/m³)
 U = fluid velocity (m/s)
 A_{wing} = area of wing (m²)
 A_{flow} = area of flow chamber (m²)
 Dp = pressure drop (Pa)

Table 1 and Figure 11 show the results of a test conducted on a delta wing 9 of the present invention having an aspect ratio AR of unity at various angles of attack θ below forty degrees under a range of fluid flow velocities U . Comparison of the actual test results to predicted results shows that the theoretical model accurately predicts the performance of the

⁴ The Strouhal number St defines the relationship between the shedding frequency to delta wing span and fluid flow velocity in the following equation:

$$(7) \quad St = f * b / U$$

f = shedding frequency (HZ)
 b = delta wing span (m)
 U = free stream velocity (m/s)

⁵ The relationship between the number of vortex revolutions per effective lamp length VR and channel residence time T can be expressed in the following equations:

$$(8) \quad VR = T * f$$

T = channel residence time (s)
 f = vortex shedding frequency (Hz)
 VR = number of vortex revolutions per effective lamp length

$$(9) \quad T = \text{eff. lamp length} / U$$

eff. lamp length = length of lamp (m)
 U = fluid flow velocity

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delta wing in the desired operating regions. Table 2 shows that the pressure drop generated by the presence of two delta wings 9 in the flow channel 7 is not equivalent to twice the theoretical pressure drop of one wing alone. The increase in pressure drop from the expected value is most likely due to the interaction of the vortices 10 from the two delta wings 9. As a result, the overall pressure drop for a system containing four delta wings 9 is expected to be approximately five times the pressure drop expected for a single wing alone. Table 3 shows the results of testing conducted on a delta wing at high (at least 40°) angles of attack θ .

TABLE 1

Experimental Observations for Test Delta WingDelta P zero reading = 13.0 mm H₂O

Temperature = 24 degrees Celsius

Delta P multiplying factor = 0.05

Density = 1.1911 kg/m³

Volt Meter zero reading = 0.007 V

From a least squares analysis (Figure 9) the support stand and open channel pressure drop is equivalent to 0.198 mm H₂O.

Pressure Drop Due to Test Delta Wing

Constant RPM = 30 percent = 4.44 m/s

Angle/Attack	Delta P (mm H ₂ O) Wing & Support	Delta P Wing Only (mm H ₂ O)	Delta P Wing Theory (mm H ₂ O)	Error (%)
10	0.2	0.002	0.0032	-37.5
20	0.22	0.022	0.0156	41.03
30	0.2375	0.0395	0.0388	1.80
35	0.255	0.057	0.0541	5.36

TABLE 2

Experimental Observations for a Pair of Test Delta Wings

Delta P zero reading = 14.9 mm H₂O
 Delta P multiplying factor = 0.05
 Volt Meter zero reading = 0.005 Volts

Temperature = 24 degrees Celsius
 Density (air) = 1.911 kg/m³

The Pair of Delta Wings were both set at an angle of attach equalling 15 degrees with the trailing edges spaced at 3/4" apart to simulate actual operating conditions at the time of testing.

Pressure Drop for Support Structure and Open Channel

<u>Velocity (m/s)</u>	<u>Delta P (mm H₂O)</u>
3.27	0.11
4.25	0.205
5.14	0.3
6.14	0.435

Pressure Drop due to Pair of Test Delta Wings

<u>Velocity (m/s)</u>	<u>Delta P (mm H₂O)</u>
3.27	0.15
4.25	0.215
5.14	0.33
6.14	0.455

Comparison of Expected to Experimental Pressure Drop of Test Pair Delta Wings

<u>Velocity (m/s)</u>	<u>Delta P Wings</u>	<u>Delta P (Support)</u>	<u>Delta P Wings Only</u>	<u>Delta P Wings Theory</u>	<u>Error (%)</u>
3.27	0.15	0.11	0.04	0.0087	-360
4.25	0.215	0.205	0.01	0.0148	32
5.14	0.33	0.3	0.03	0.0216	-39
6.14	0.455	0.435	0.02	0.0308	35

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TABLE 3

Experimental Observations for Test Delta Wing at High Angles of AttachDelta P zero reading = 14.2 mm H₂O

Temperature = 24 degrees Celsius

Delta P multiplying factor = 0.05

Density = 1.1911 kg/m³

Volt Meter zero reading = 0.0111 V

Pressure Drop for Support Structure and Open Channel

Velocity (m/s)	Delta P (mm H ₂ O)	Delta P (inches H ₂ O)
2.42	0.05	0.002
4.23	0.185	0.0073
5.10	0.25	0.0098

Pressure Drop due to Test Delta Wing

Alpha = 40 degrees

Velocity (m/s)	Delta P (mm H ₂ O)	Delta P (inches H ₂ O)	Delta P (wing only)	Delta P (wing theory)	Error (%)
2.43	0.085	0.0033	0.035	0.021	-66.7
4.24	0.235	0.0093	0.05	0.064	21.9
5.08	0.335	0.132	0.085	0.093	8.6

Alpha = 50 degrees

Velocity (m/s)	Delta P (mm H ₂ O)	Delta P (inches H ₂ O)	Delta P (wing only)	Delta P (wing theory)	Error (%)
2.45	0.075	0.003	0.025	0.033	24.2
4.24	0.245	0.0096	0.06	0.098	38.8
5.04	0.345	0.136	0.095	0.138	31.1

Delta Wing Flow Visualization

<u>Angle of Attack</u>	<u>Velocity</u>	<u>Notes</u>
40	4.27	Vortex breakdown appears to occur at the end of the delta wing. Extremely violent whipping action of the string at this point.
50	4.21	Vortex breakdown appears to occur at approximately two fifths the length of the delta wing. Extremely violent whipping action of the string at this point

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As a result of the testing, the optimum delta wing 9 design for the preferred embodiment of the present invention conforms to the following specification, with a system of four delta wings 9 per lamp tube 13 or spacer 6 creating a total of eight vortices 10:

Root chord $c = 7.37$ inches

Span $b = 3.685$ inches

Leading edge bevel angle = 45 degrees (Figure 8b)

Angle of attack $\phi = 20$ degrees

While presently preferred embodiments of practicing the invention have been shown and described with particularity in connection with the accompanying drawings, the invention may otherwise be embodied within the scope of the following claims.

WHAT IS CLAIMED IS:

1. An apparatus for mixing at least one fluid flowing through a fluid system, comprising:

A. at least one first member with at least one surface elongated in at least one dimension such that the axis of one of said elongated surfaces is substantially aligned with the direction of said fluid flow;

B. at least one second member having at least one surface located in spaced relationship to one of said elongated surfaces that is substantially aligned with the direction of said fluid flow;

wherein at least one said surface of said at least one second member is shaped and oriented to interact with said fluid flow to create at least one vortex in said fluid that rotates with an axis substantially aligned along the direction of said fluid flow.

2. The apparatus of Claim 1, wherein said shaped surface of said second member is triangularly shaped.

3. The apparatus of Claim 1, wherein said shaped surface of said second member is inclined at an angle to the direction of said fluid flow.

4. The apparatus of Claim 1, wherein at least two vortices are created such that each said vortex rotates in the same direction.

5. The apparatus of Claim 1, wherein at least two vortices are created such that said vortices rotate in an opposed direction to each other.

6. An apparatus for mixing at least one fluid flowing through a fluid system, comprising:

A. an array of spaced apart first members each having at least one surface elongated in at least one dimension such that the axis of one of said elongated surfaces is substantially aligned with the direction of said fluid flow;

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B. a plurality of second members each having at least one surface located in spaced relationship to one of said elongated surfaces that is substantially aligned with the direction of said fluid flow;

wherein at least one said surface of at least one said second member is shaped and oriented to interact with said fluid flow to create at least one vortex in said fluid that rotates with an axis substantially aligned along the direction of said fluid flow.

7. The apparatus of Claim 6, wherein at least two vortices are created such that each said vortex rotates in the same direction.

8. The apparatus of Claim 6, wherein at least two vortices are created such that said vortices rotate in an opposed direction to each other.

9. The apparatus of Claim 6, wherein said shaped surface of said second member is triangularly shaped.

10. The apparatus of Claim 6, wherein said shaped surface of said second member is inclined at an angle to the direction of said fluid flow.

11. The apparatus of Claim 6, wherein at least one pair of vortices is created such that said vortices in said pair rotate in an opposed direction to each other.

12. The apparatus of Claim 6, wherein at least two pairs of vortices are created such that each said vortex in one said pair rotates in the same direction and such that said vortices in said other pair rotate in an opposed direction to each other.

13. The apparatus of Claim 6, wherein said array is uniform.

14. The apparatus of Claim 6, wherein said array is not uniform.

15. The apparatus of Claim 6, further comprising an array of spaced apart third members interspersed between said first members and each having at least one surface

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elongated in at least one dimension such that the axis of one of said elongated surfaces is substantially aligned with the direction of said fluid flow.

16. The apparatus of Claim 6 wherein said axes of said first members are arranged substantially in the form of a square.

17. The apparatus of Claim 15 or 16, wherein said axes of said third members are arranged substantially in the form of a square.

18. The apparatus of Claim 10, wherein said second members are arranged in pairs such that said angle of each member in said pair is of substantially equal magnitude and of substantially opposite inclination.

19. The apparatus of Claim 1 or 6, further comprising two said second members in spaced relationship to each said first member.

20. The apparatus of Claim 1 or 6, further comprising four said second members in spaced relationship to each said first member.

21. The apparatus of Claim 1 or 6, wherein the spacing of the center axis of each said vortex from a tip of said shaped surface of said second member is determined by the width of one side of said shaped surface.

22. The apparatus of Claim 21, wherein said center axis is spaced from a tip of said shaped surface a distance of approximately one quarter of the width of said side of said shaped surface.

23. The apparatus of Claim 1 or 6, wherein the position of the center axis of each said vortex is determined by the magnitude of said angle of inclination of said shaped surface.

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24. The apparatus of Claim 23, wherein said center axis is positioned from said first member a distance of approximately one-half the magnitude of said angle of inclination.

25. The apparatus of Claim 15, wherein the position of the center axis of each said vortex is determined by the magnitude of said angle of inclination of said triangular surface.

26. The apparatus of Claim 25, wherein said center axis is positioned from said third member a distance of approximately one-half the magnitude of said angle of inclination.

27. The apparatus of Claim 1 or 6, wherein said first members are configured to permit removal of said first members from said system.

28. The apparatus of Claim 15, wherein said third members are configured to permit removal of said members from said system.

29. The apparatus of Claim 1, wherein said fluid system causes a chemical reaction within said fluid.

30. The apparatus of Claim 29, wherein said chemical reaction accomplishes disinfection of said fluid.

31. The apparatus of Claim 30, wherein said fluid system accomplishes said disinfection by use of ultraviolet radiation.

32. The apparatus of Claim 31, wherein said first members comprise lamps which generate said ultraviolet radiation.

33. The apparatus of Claim 32, where said lamps are made of a material comprising quartz.

34. The apparatus of Claim 6, wherein said fluid system causes a chemical reaction within said fluid.

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35. The apparatus of Claim 34, wherein said chemical reaction accomplishes disinfection of said fluid.

36. The apparatus of Claim 35, wherein said fluid system accomplishes said disinfection by use of ultraviolet radiation.

37. The apparatus of Claim 36, wherein said first members comprise lamps which generate said ultraviolet radiation.

38. The apparatus of Claim 37, where said lamps are made of a material comprising quartz.

39. A method of disinfecting at least one fluid comprising passing said fluid through the apparatus of Claim 29, 30, 31, 32, 33, 34, 35, 36, 37 or 38.

40. The apparatus of Claim 1 or 6, wherein said second member is selected from the group consisting of baffles, propellers and contoured flow tubes,

41. The apparatus of Claim 1 or 6, wherein said spaced relationship is such that said second member is located upstream of said first member.

42. The apparatus of Claim 1 or 6, wherein said spaced relationship is such that said second member is located adjacent to said elongated surface of said first member.

43. The apparatus of Claim 6 or 16, wherein said second members are arranged so as to create eight vortices adjacent to each said first member such that each said vortex is adjacent to at least one other said first member.

44. The apparatus of Claim 43, wherein each said vortex rotates in an opposed direction to at least one other said vortex.

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45. The apparatus of Claim 44, wherein all said vortices rotate in the same direction.

46. The apparatus of Claim 17, wherein said second members are arranged so as to create eight vortices adjacent to each said first member such that each said vortex is adjacent to at least one other said first member and to at least one said third member.

47. The apparatus of Claim 46, wherein each said vortex rotates in an opposed direction to at least one other said vortex.

48. The apparatus of Claim 47, wherein all said vortices rotate in the same direction.

49. The apparatus of Claim 6 wherein said axes of at least three said first members are arranged substantially in the form of a triangle.

50. The apparatus of Claim 49, wherein said second members are arranged so as to create six vortices adjacent to each said first member.

51. The apparatus of Claim 50, wherein each said vortex rotates in an opposed direction to at least one other said vortex.

52. The apparatus of Claim 51, wherein all said vortices rotates in the same direction.

53. The apparatus of Claim 49, further comprising an array of spaced apart third members interspersed between said first members and each having at least one surface elongated in at least one dimension such that the axis of one of said elongated surfaces is substantially aligned with the direction of said fluid flow.

54. The apparatus of Claim 53, wherein said second members are arranged so as to create an even number of vortices adjacent to each said first member.

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55. The apparatus of Claim 54, wherein all said vortices rotates in the same direction.

56. The apparatus of Claim 55, wherein each said vortex rotates in an opposed direction to all other said vortices.

57. The apparatus of Claim 1 or 6, wherein all said vortices rotate in the same direction.

58. The apparatus of Claim 23, wherein the position of the center axis of each said vortex relative to said first member is determined by the magnitude of said angle of inclination of said shaped surface and the spacing of said first member from said second member.

59. The apparatus of Claim 25, wherein the position of the center axis of each said vortex relative to said third member is determined by the magnitude of said angle of inclination of said shaped surface and the spacing of said first member from said third member.

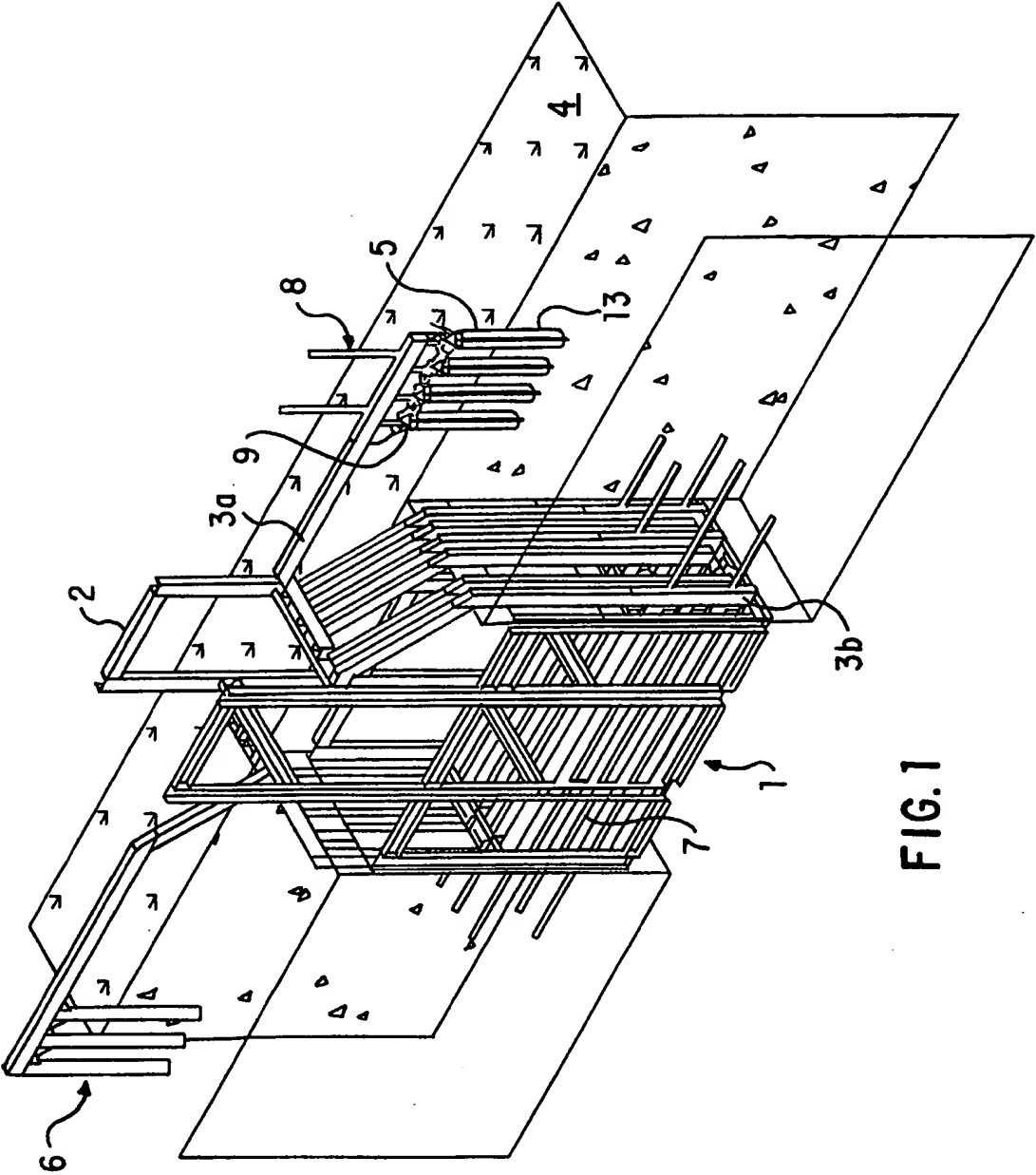


FIG. 1

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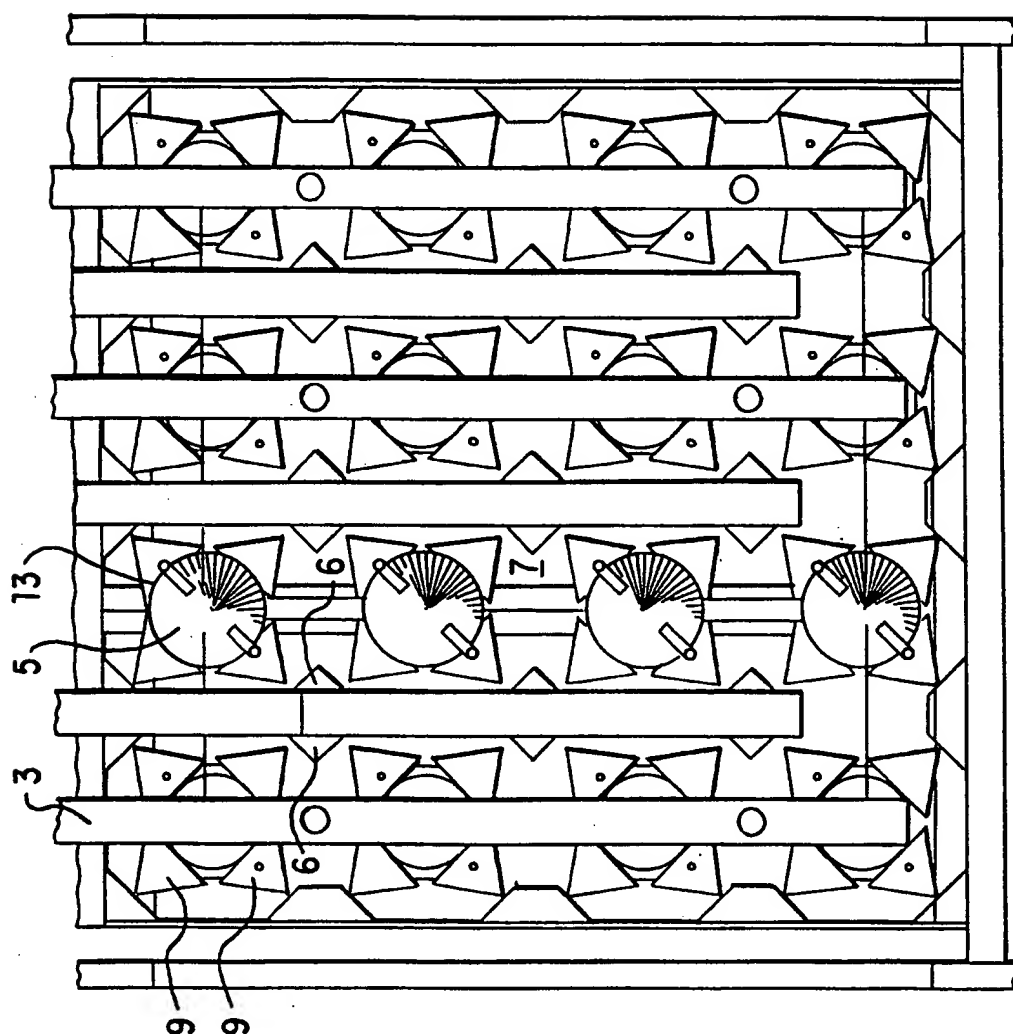


FIG. 2a

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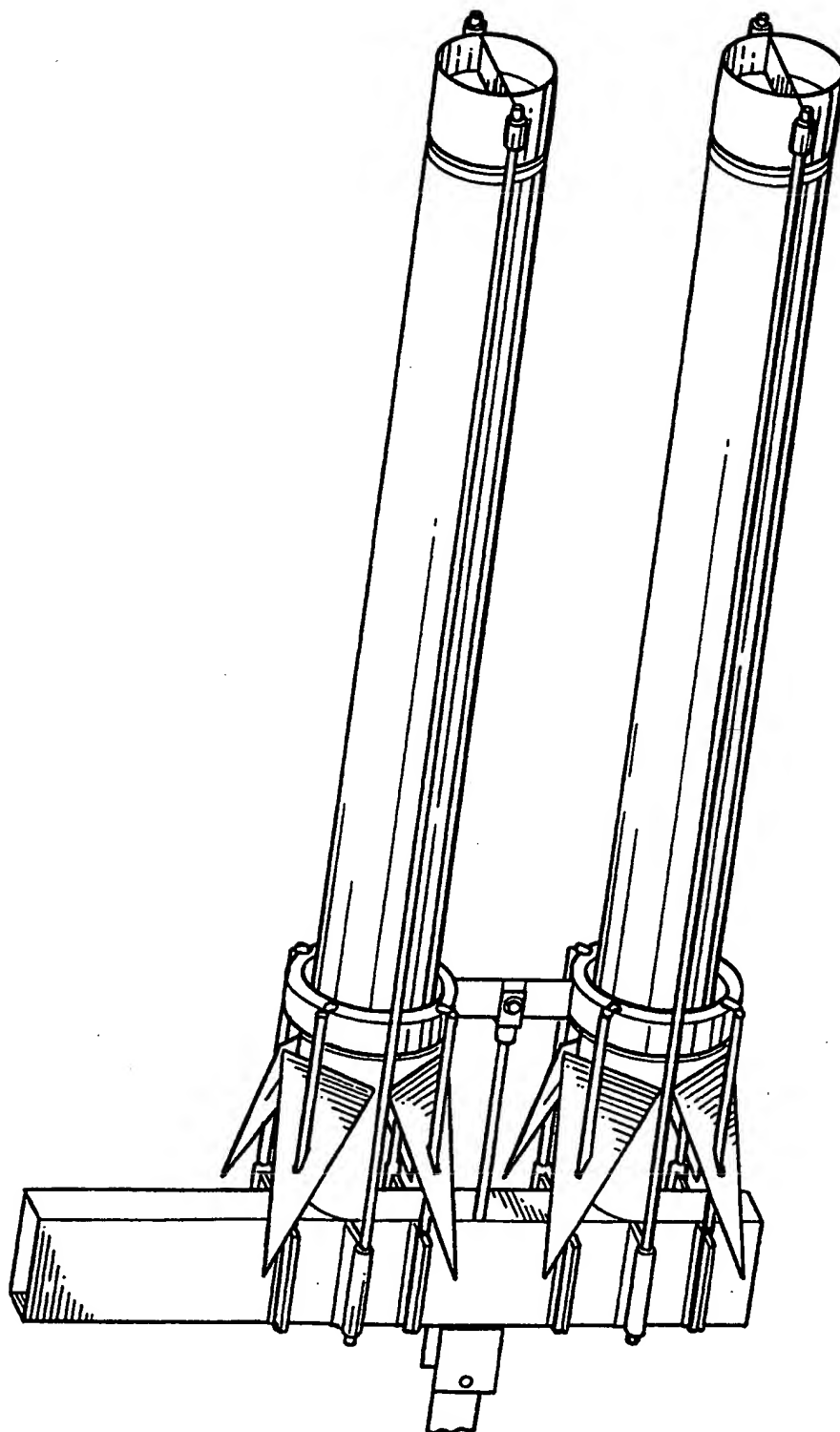


FIG. 2b

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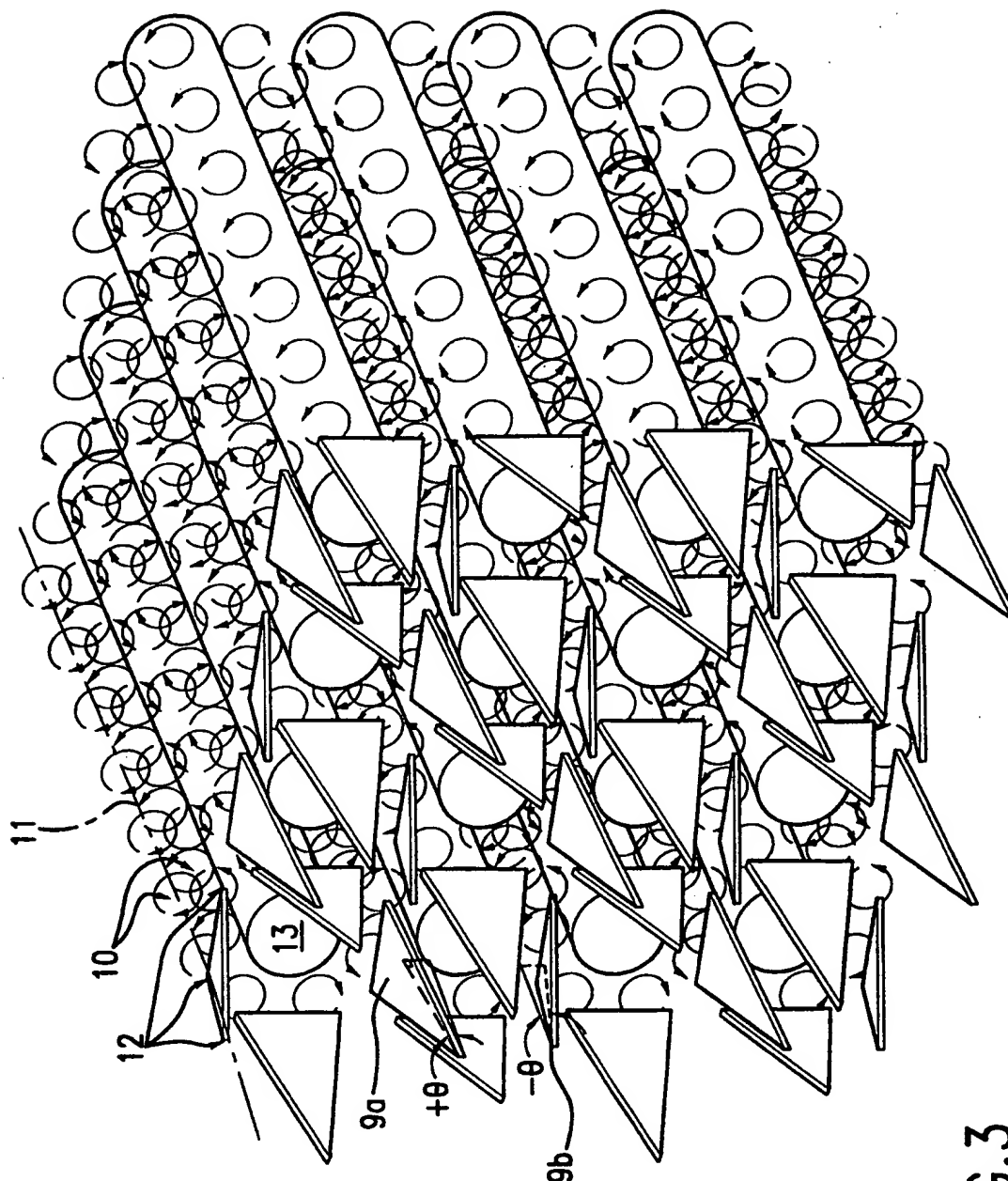


FIG. 3

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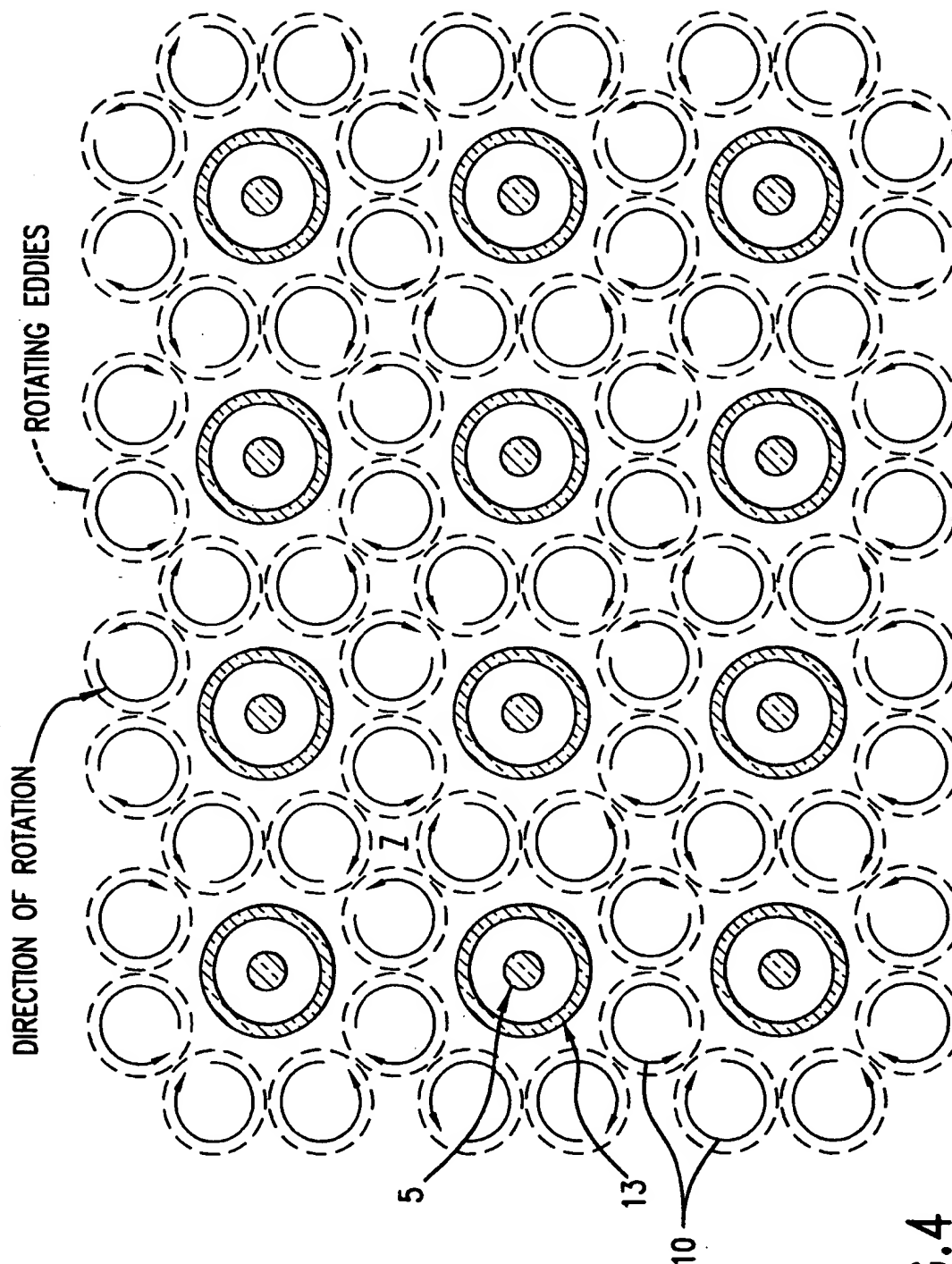


FIG.4

FIG. 6

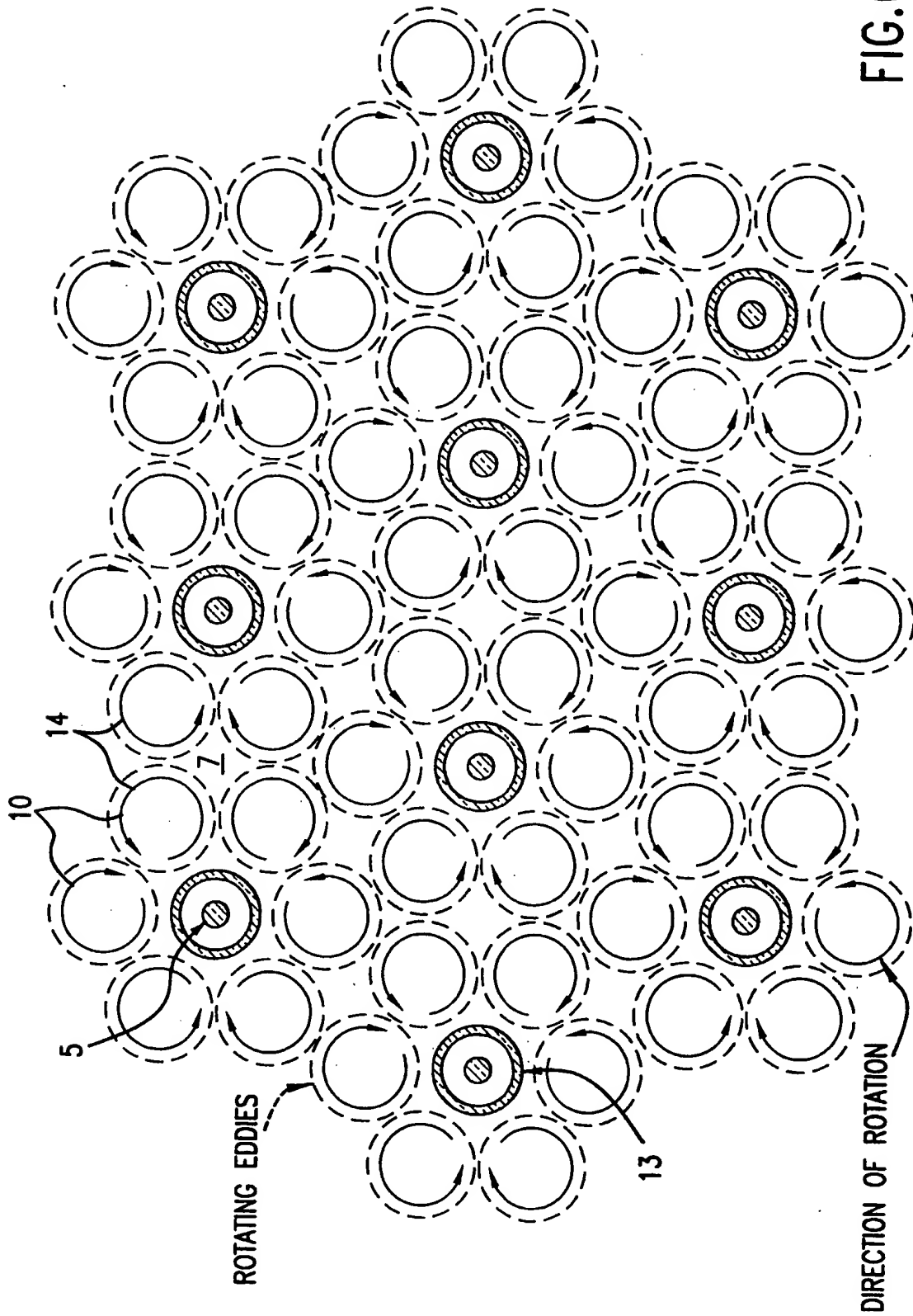
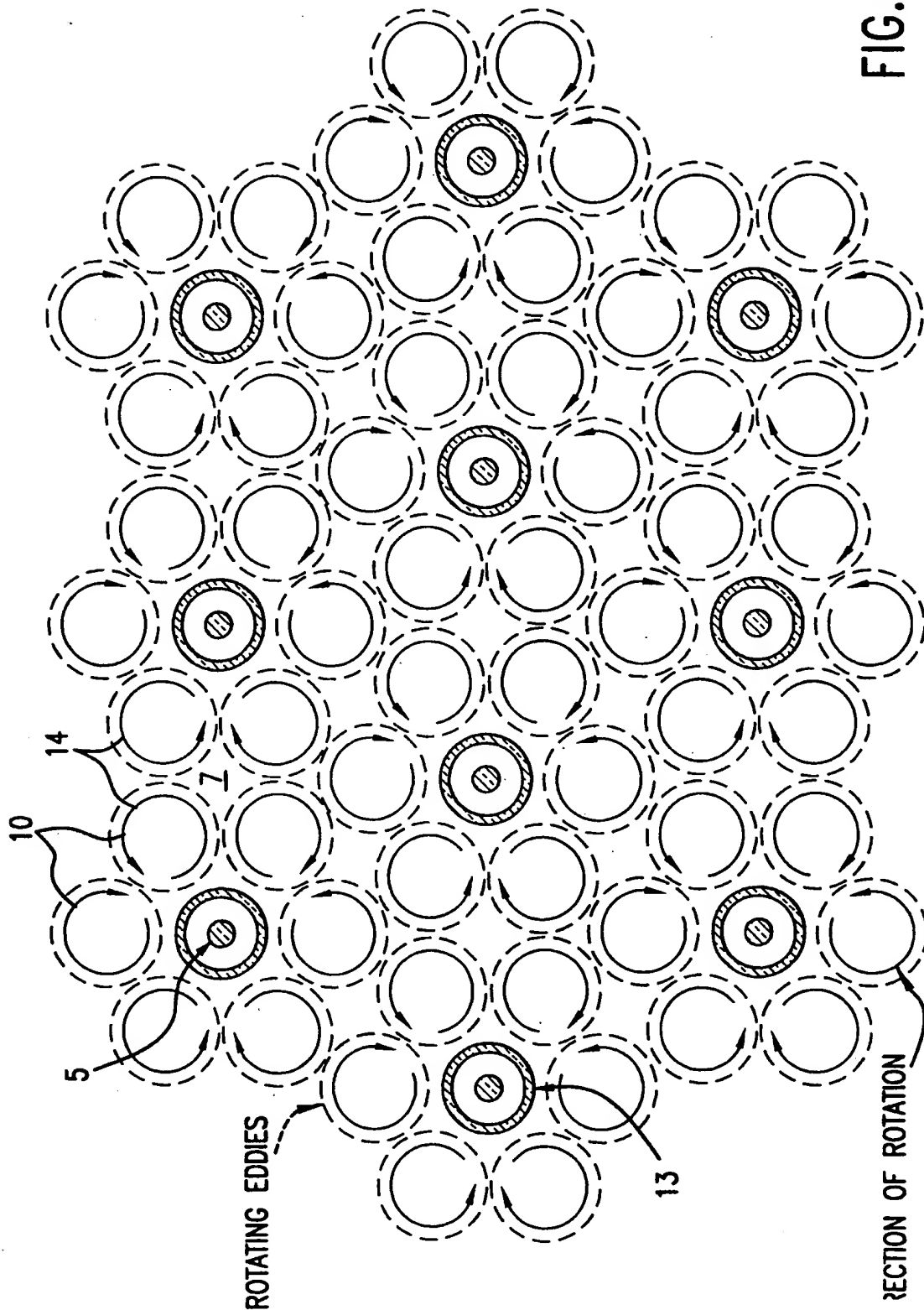


FIG. 6



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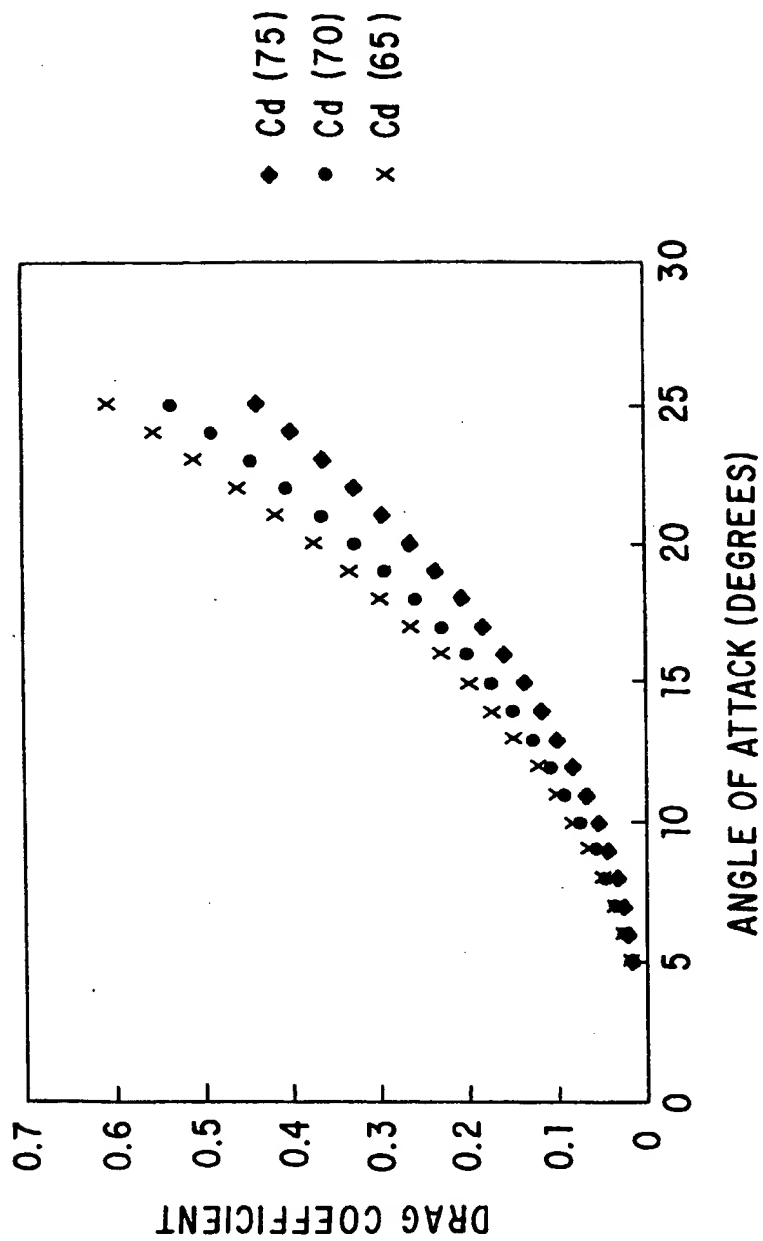


FIG. 7

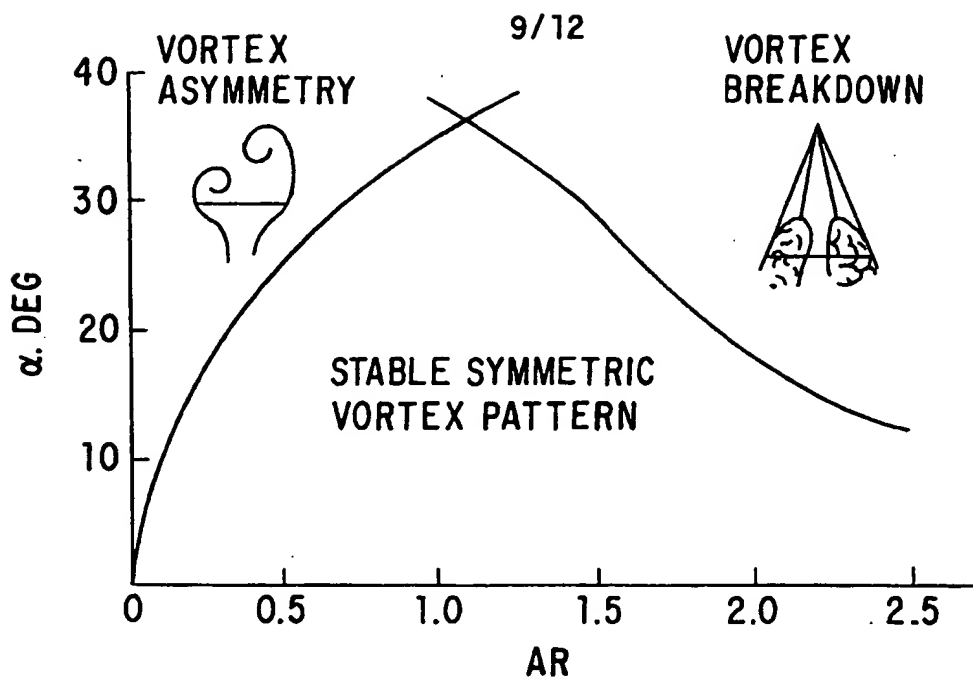


FIG. 8a

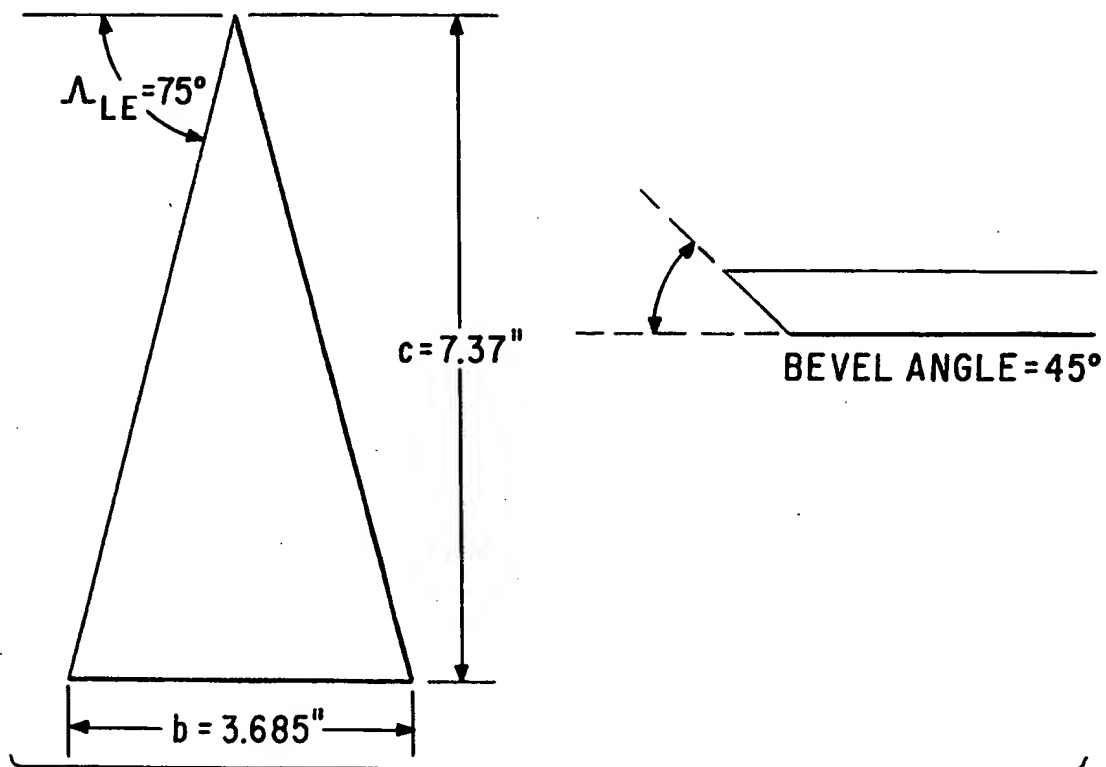


FIG. 8b

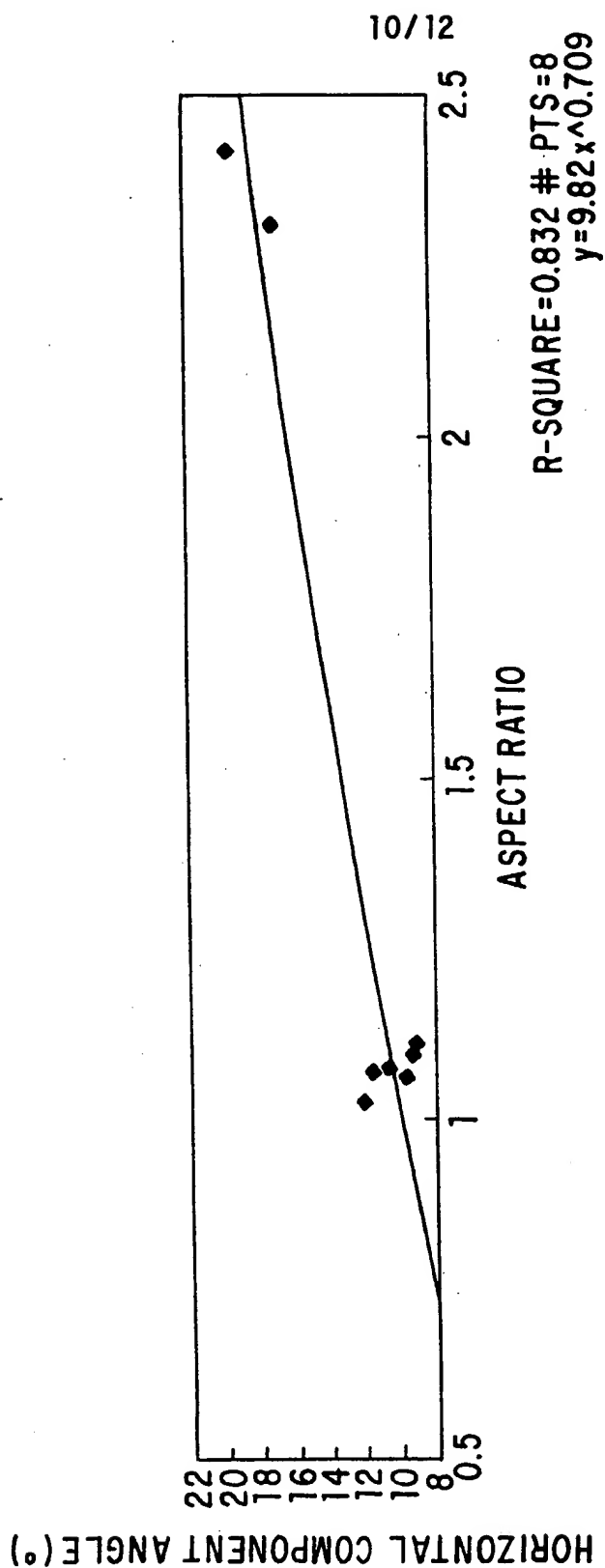


FIG. 9

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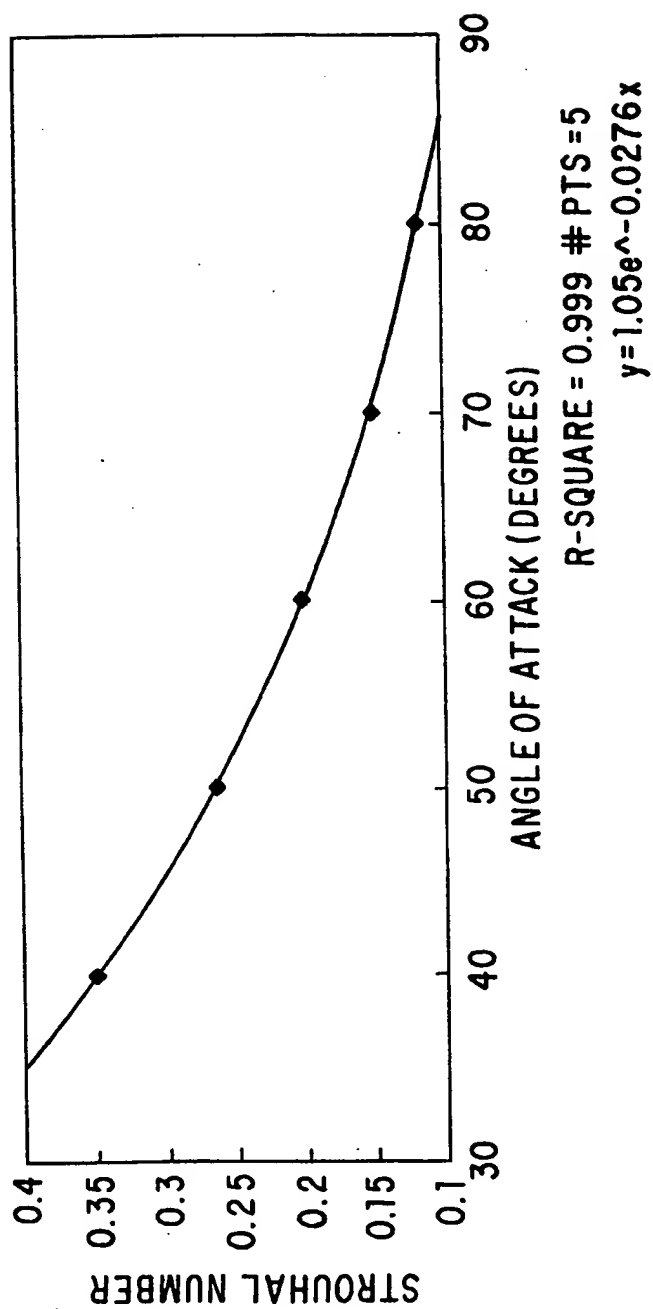


FIG. 10

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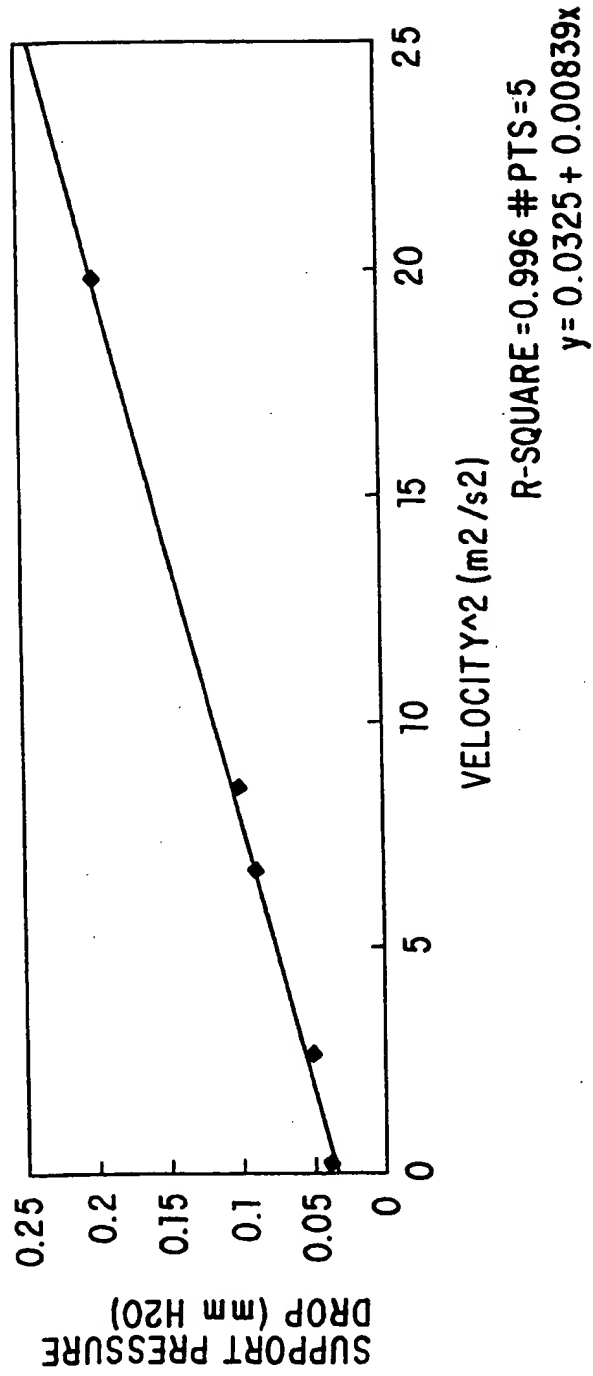


FIG. 11

INTERNATIONAL SEARCH REPORT

Int'l. Application No

PCT/US 98/19650

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B01F5/00 C02F1/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 B01F C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 268 968 A (ITALIA ULTRAVIOLET TECHNOLOGY) 1 June 1988 see abstract; claims 1-3; figures see column 1, line 20 - column 1, line 54 see column 3, line 14 - column 31, line 44 ---	1-7, 13-15, 27-40, 42,43, 45,46, 48,49, 52-57,59
X	WO 94 02680 A (KAMYR INC) 3 February 1994 see abstract; claims 1,12; figure 1 ---	1,29,34
X	US 5 540 848 A (ENGELHARD ROLF) 30 July 1996 see abstract; claims 1,19; figures --- -/--	1,29-34

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

5 January 1999

Date of mailing of the international search report

13/01/1999

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Dugdale, G

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/19650

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	<p>EP 0 802 163 A (PET MATE LTD)</p> <p>22 October 1997</p> <p>see abstract; figures 1,3</p>	29-34

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 98/19650

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